The Cosmological Content of Galaxy Redshift Surveys
or
Why are FoMs all over the map?

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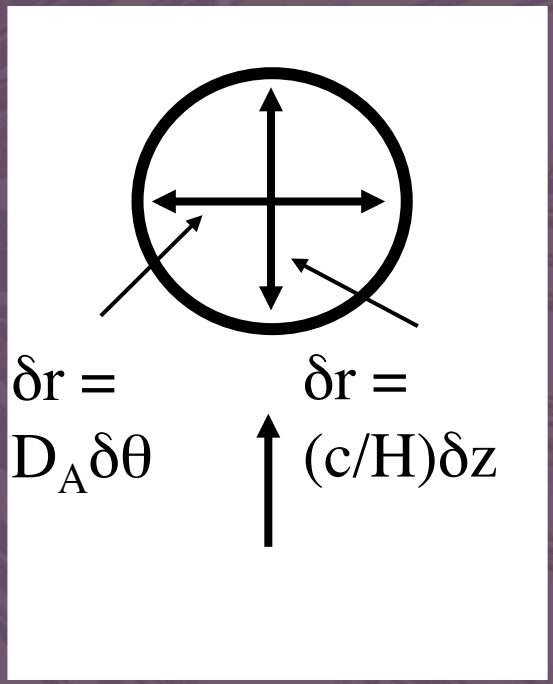
ations from Planck, and do not include CMB lensing.

	Modified Gravity	Dark Matter	Initial Conditions	Dark Energy		
Parameter	γ	m_ν/eV	f_{NL}	w_p	w_a	*FoM*
Euclid Primary	0.010	0.027	5.5	0.015	0.150	430
Euclid All	0.009	0.020	2.0	0.013	0.048	1540
Euclid+Planck	0.007	0.019	2.0	0.007	0.035	4020
Current	0.200	0.580	100	0.100	1.500	~10
Improvement Factor	**30**	**30**	**50**	**>10**	**>50**	**>300**

Four main ways a WFIRST-like redshift survey can constrain cosmic acceleration:

BAO: Constrains $D_A(z)$ and $H(z)$. Robust – likely to be limited by statistics rather than systematics.



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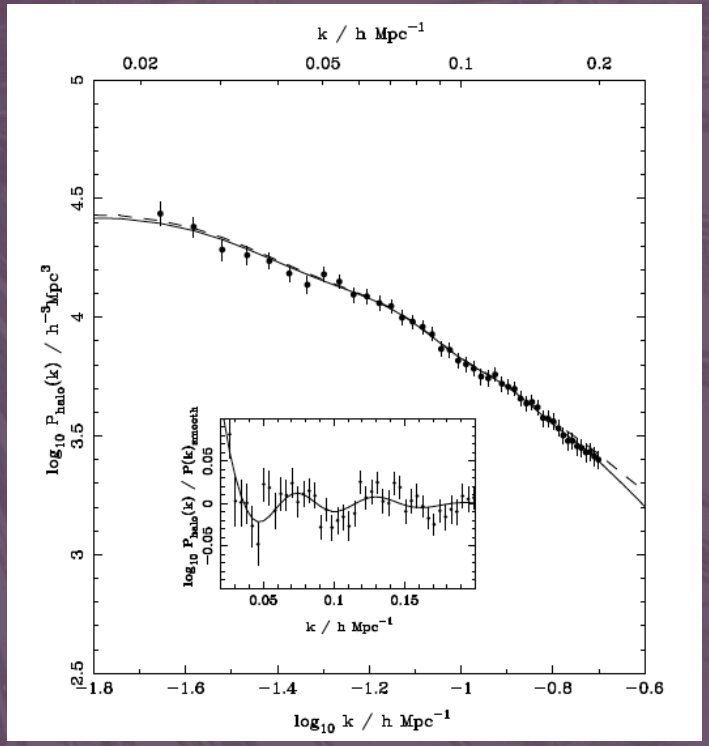

Reid et al. 2010, SDSS DR7

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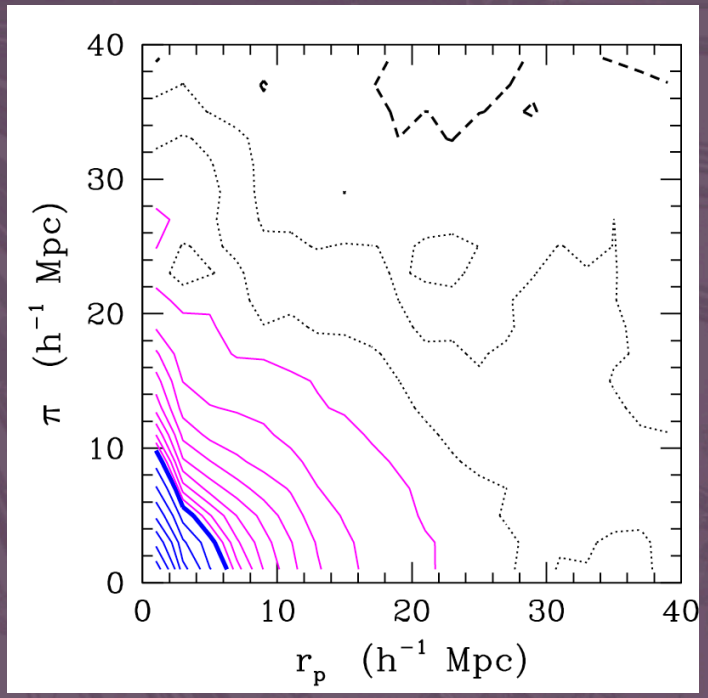

Zehavi et al. 2011, SDSS DR7

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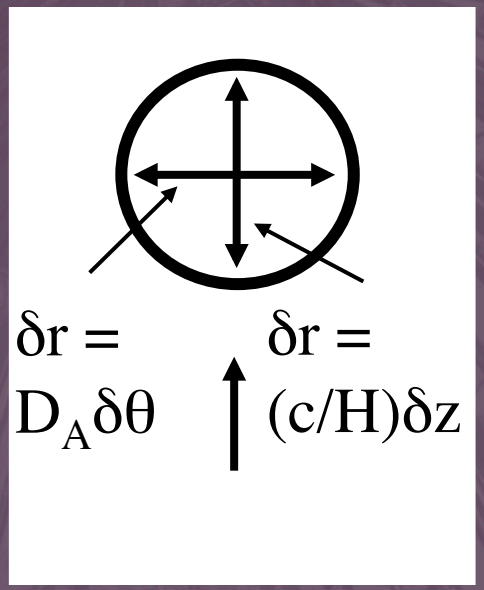
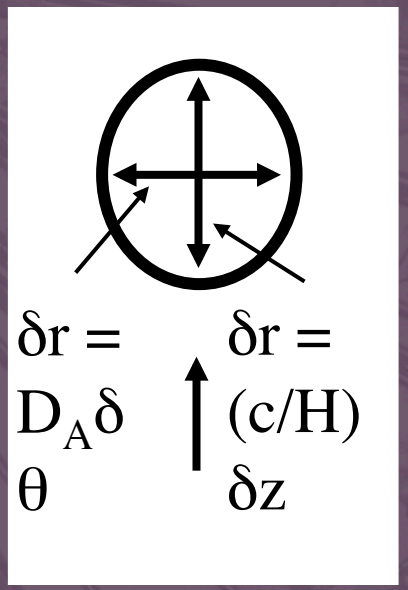
Alcock-Paczynksi (AP) test:





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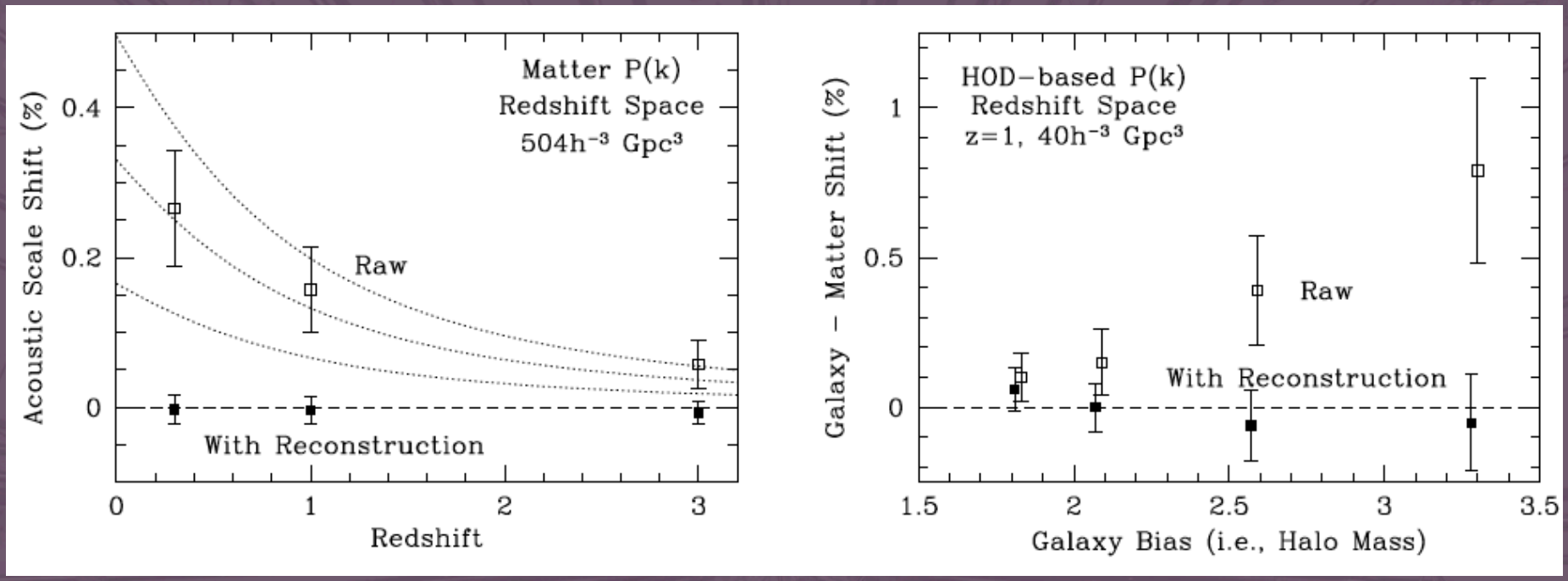
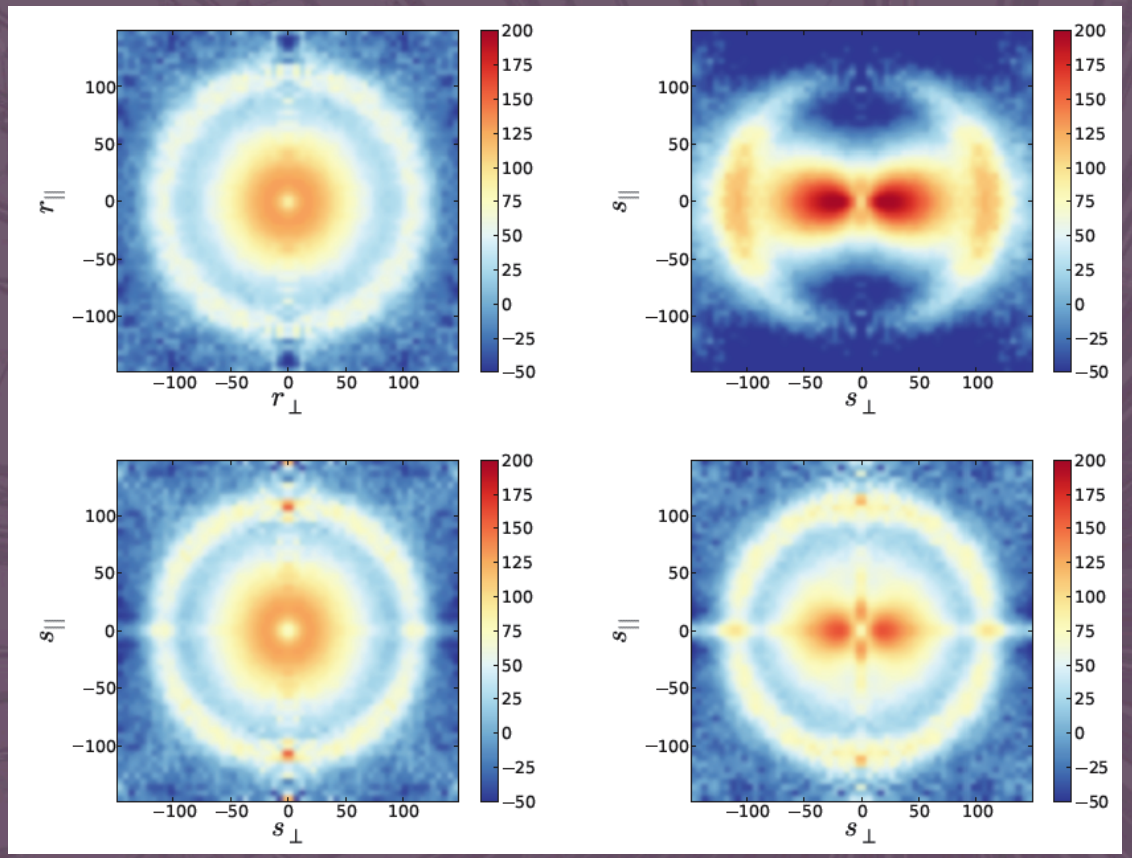
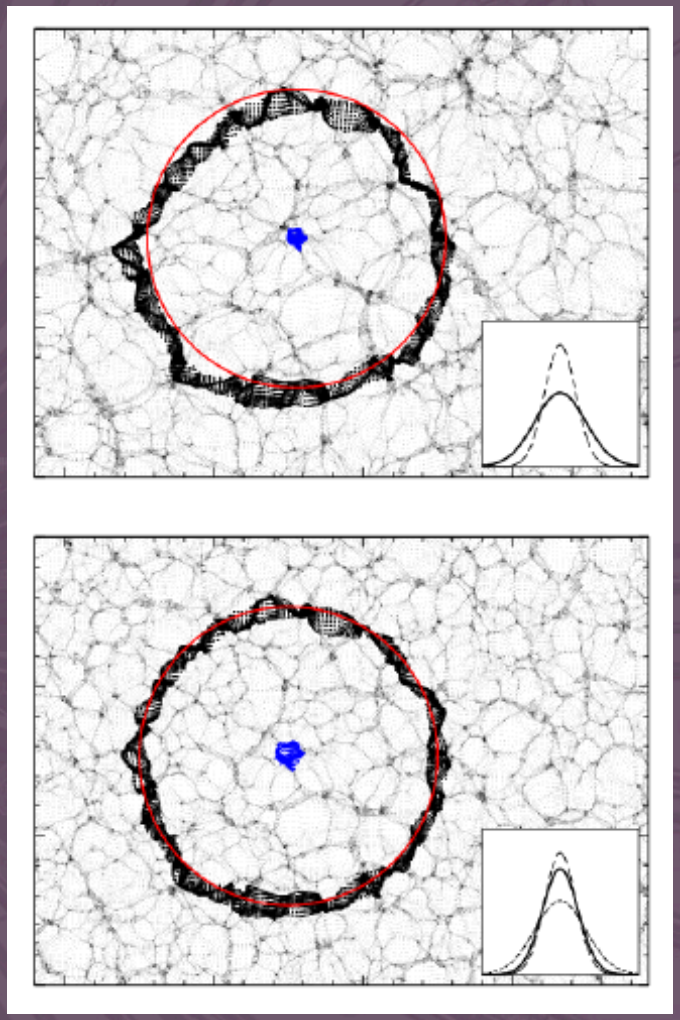
AP test: Demanding statistical isotropy of structure constrains $H(z)D_A(z)$.
Potentially large gains if measured at smaller scale than BAO.
Can transfer BAO/SN measures of $D_A(z)$ to $H(z)$, improving dark energy sensitivity.
RSD (the peculiar velocity part) is a systematic for AP.



BAO robustness: Current simulations imply 0.1 – 0.3% shifts of acoustic scale from non-linear evolution, somewhat larger for highly biased tracers. Reconstruction removes shift at level of 0.1% or better.

Figs available in review article, originally from Seo et al. (2010) and Mehta et al. (2011).

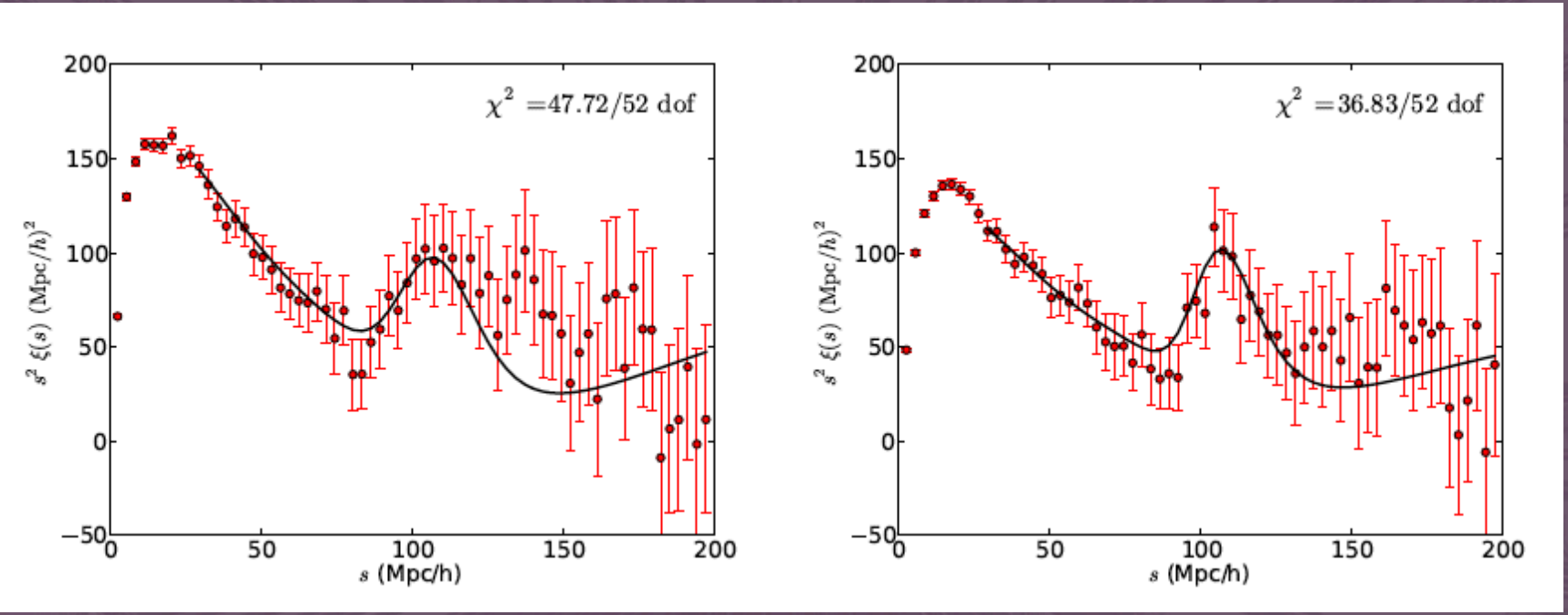




BAO reconstruction sharpens acoustic peak and removes non-linear shift by "running gravity backwards" to (approximately) recover linear density field.

Figs from Padmanabhan et al. 2012.

Application to SDSS DR7



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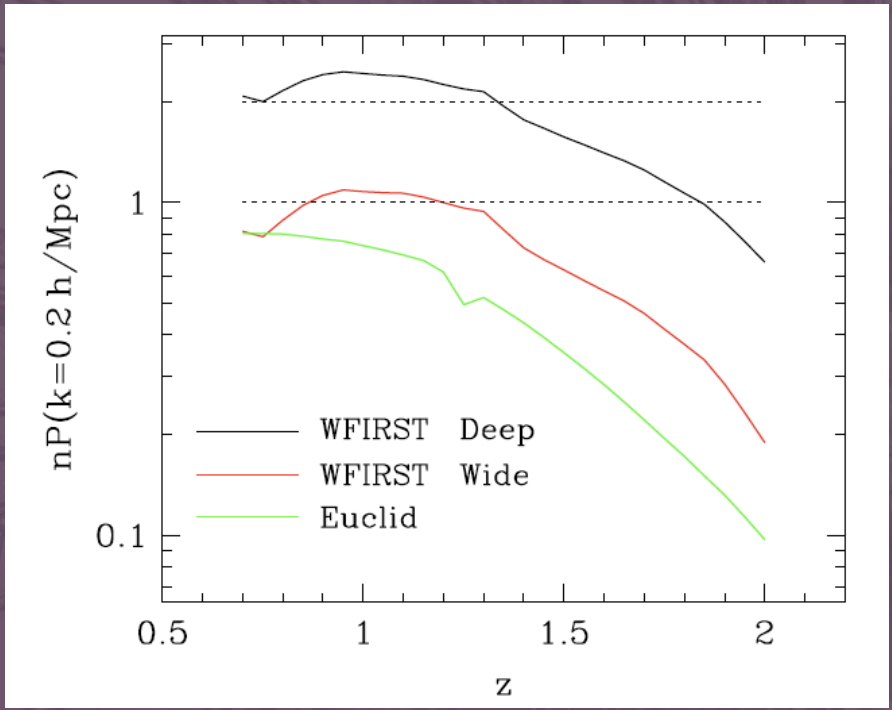
Fractional error per mode in power spectrum is

$(\sigma_P / P) = (1 + 1/nP)$, n = space density, P = power amplitude



Based on calculations by C. Hirata

- Euclid is shot-noise dominated at all z.
- WFIRST-wide is shot-noise dominated at $z > 1.4$.
- WFIRST-deep is close to sample variance limited.
- But $nP \geq 2$ probably better criterion than $nP \geq 1$.

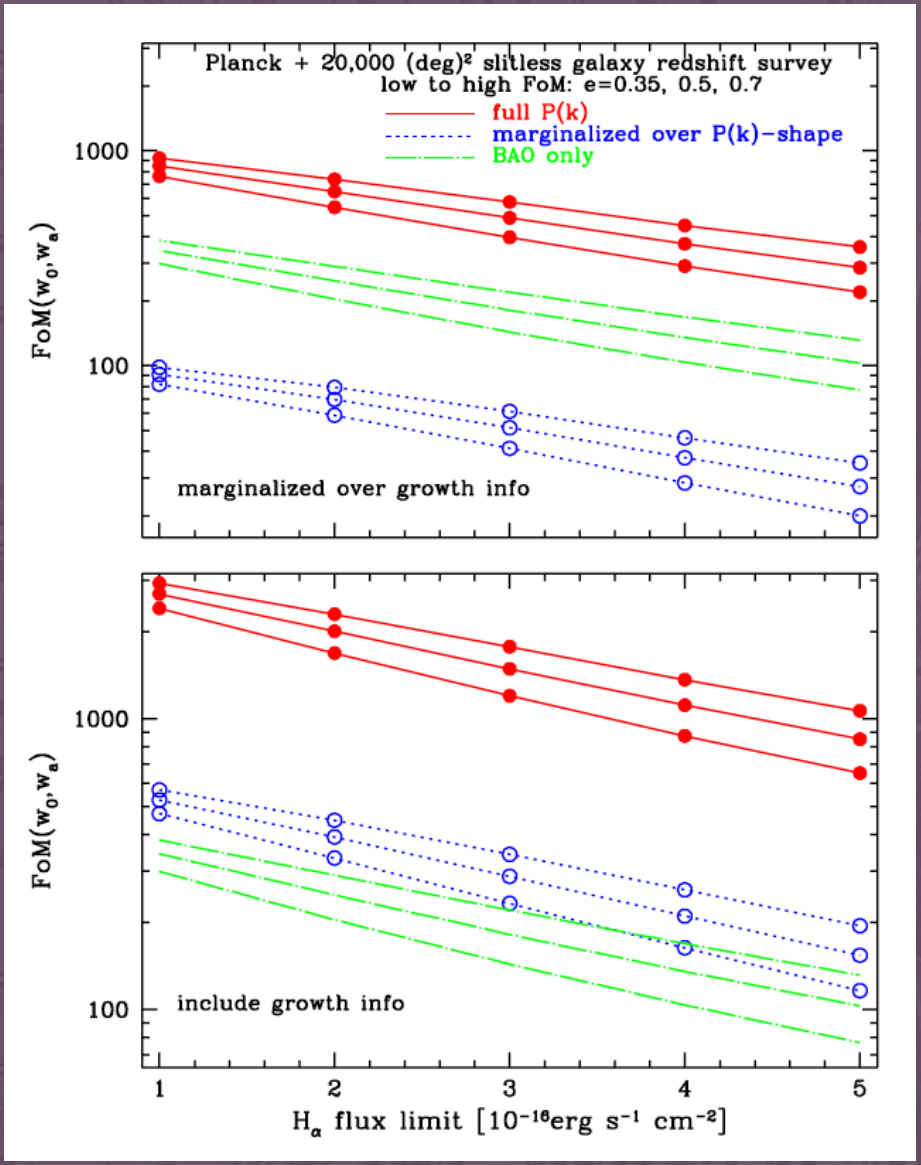
Why are FoMs for galaxy redshift surveys all over the map?

The big effect: BAO only or "full P(k)" including RSD, AP?
In absence of theoretical systematics, there is more info at sub-BAO scales.

Reconstruction improvement of BAO?
Marginalizing over scale-dependent bias in P(k)?

For full P(k), what is k_{max} (set by modeling uncertainty)?
Roughly: $N_{modes} \sim k_{max}^3$ and $FoM \sim \sigma^{-2} \sim (N_{modes})^{-1}$

Assuming GR or allowing deviations from GR-predicted growth?
Does the information in RSD go all to w(z) or mainly to growth parameters?



Not assuming GR

Assuming GR, note change of vertical axis.

Y. Wang, W. Percival, et al. 2010

Overlapping redshift and WL surveys

Linear perurbation theory for RSD implies

$$\Delta_{g,s} = [b + f(z)\mu^2]\,\Delta_{m,r} \quad ; \quad f(z) = d\ln G/d\ln a \approx [\Omega_m(z)]^{\gamma}$$

$$\Delta_{m,r} \sim \sigma_8(z)$$

Use μ-dependence of $\langle(\Delta_{g,s})^2\rangle$ to back out $\sigma_8(z)f(z)$.
Tracer populations of different b yield additional leverage.

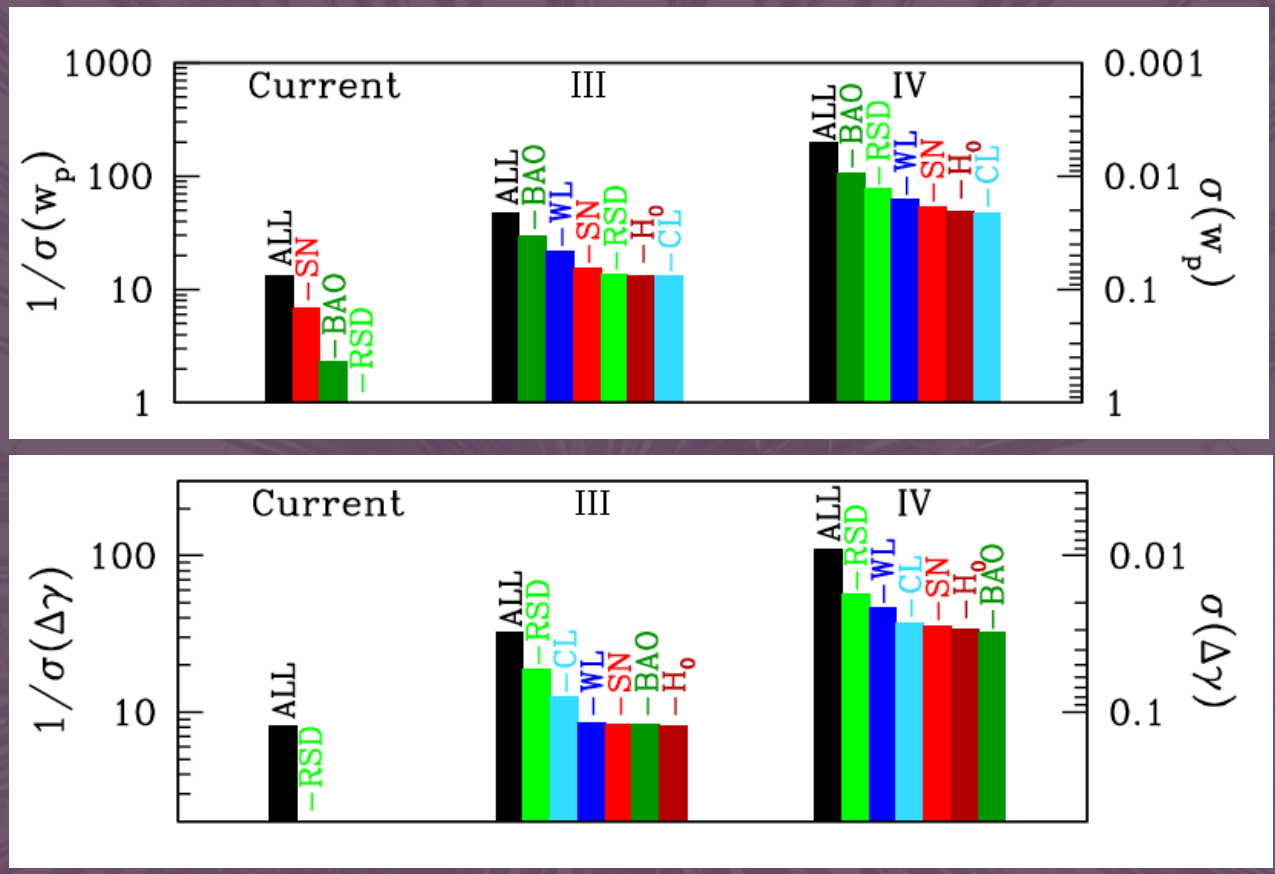
Recent papers (Bernstein & Cai 2011; Gaztanaga et al 2011) suggest that overlapping WL and spectroscopic surveys can yield significantly better constraints than non-overlapping surveys.

In essence, WL by redshift survey galaxies calibrates b.

Expected gain is quite dependent on details of surveys.

Also gain from improved photo-z constraints via cross-correlation.

Forecast errors from a notional 6-probe program (+ CMB)



Acceleration review, fig. by M. Mortonson

Probes dropped in order of leverage. Note *potentially* powerful contribution from redshift-space distortions (RSD).

Conclusions

- BAO-only forecasts are conservative, maybe by a large factor.
- RSD can be a powerful constraint on growth of structure, competitive with or stronger than WL.
- But theoretical systematics for non-BAO methods remain highly uncertain.
- Euclid and WFIRST-wide surveys still well below sampling variance limit over much of their volume. Additional factors (reconstruction, RSD modeling) probably favor higher nP, though this has not really been investigated.
- Potential return from redshift surveys is high, may not be dominated by BAO.